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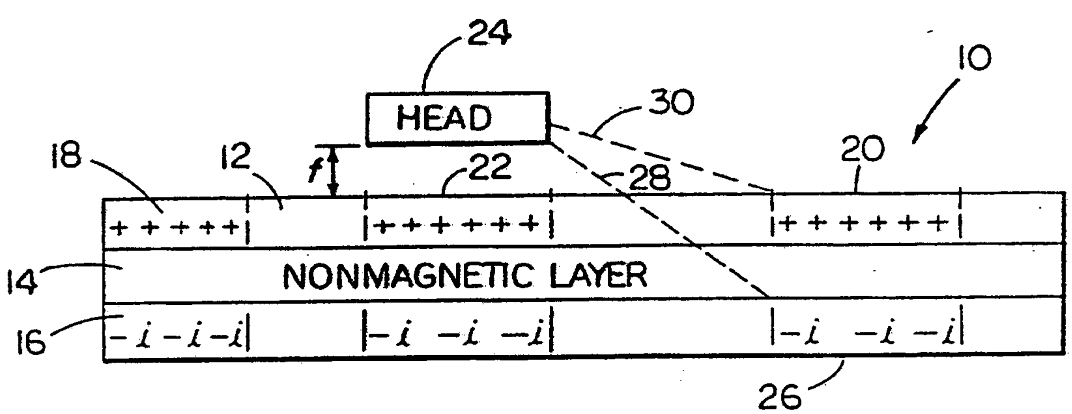

(57) Abstract

The magnetic medium includes a soft magnetic layer separated from the hard magnetic recording layer by a non-magnetic buffer layer. Virtual magnetic images induced in the soft magnetic layer reduce off-track magnetization seen by the recording head. Thus, interference caused by tracks adjacent to the track being read is reduced.

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MAGNETIC MEDIUM FOR LONGITUDINAL RECORDING

Background of the Invention

This invention relates to a magnetic medium for longitudinal recording which suppresses off-track fringing signals that interfere with accurate readback of data on a track of interest.

As a recording head flies over a track of data, flux from this track and adjacent tracks is detected during a read operation. In the past, adjacent tracks were separated by a wide enough intertrack space to make the flux reaching the head from an adjacent track insignificant compared to the flux from the track of interest. The problem of adjacent track interference becomes more severe when track density is high. In this case the signal of interest is relatively weak and the adjacent track is sufficiently close that its flux is significant.

Summary of the Invention

According to one aspect of the invention a magnetic medium for longitudinal recording includes a soft magnetic layer separated from the hard magnetic recording layer by a nonmagnetic buffer layer. It is preferred that the thickness of the soft magnetic layer be greater than the thickness of the hard magnetic recording layer. A suitable magnetic thickness for the soft magnetic layer is approximately 30% thicker than the hard magnetic layer. The magnetic thickness is equal to the product of the geometric thickness and the remnant magnetization. It is also preferred that the nonmagnetic layer thickness be in the range of 0.5 to 2 times the effective fly height of the magnetic head. In yet another aspect of the invention, the soft magnetic

layer has low permeability to avoid shorting out the head poles which reduces head efficiency.

In another aspect of the invention, the head generates magnetic fields during read to saturate the soft magnetic layer in the medium so as to cancel the effect of the image charges below the head. This technique will allow the use of very thin buffer layers and will facilitate using a two-pole head to read.

A uniaxial anisotropy is induced in a radial direction in the soft magnetic layer of the medium of this invention. The uniaxial anisotropy may be induced by an applied magnetic field during deposition, by annealing the medium in a magnetic field after deposition, by controlling the angle of incidence during vacuum deposition, or by pretexturing the substrate on which the soft magnetic layer is deposited.

Brief Description of the Drawing

The single figure of the drawing is a cross-sectional view of the magnetic medium.

Description of the Preferred Embodiment

First of all, the theory on which the present invention is based will be discussed in conjunction with the figure of the drawing. A magnetic medium 10 includes a hard magnetic recording layer 12, a nonmagnetic buffer layer 14, and a soft magnetic underlayer 16. To understand the effect of the soft magnetic layer 16, it is best to think in terms of the theory of "virtual" images. The magnetization of the hard magnetic layer 12 is treated as a series of discreet magnetic charges 18. These "charges" (+) located in the hard magnetic layer 12 behave as if they induce negative image charges (-i) within the soft magnetic layer 16. In a conventional medium, charges in a track 20 adjacent to a track 22 beneath a head 24

would interfere with the ability of the head 24 to read the track 22 information accurately. (The medium 10 is generally configured as a disc, and motion of the medium 10 is into or out of the plane of the figure.) Because of the soft magnetic layer 16, charges in the hard magnetic layer 12 at the track 20 induce negative image charges 26. When the thicknesses of the layers 14 and 16 are small, the distance from the negative image charges 26 to the head 24 is only slightly greater than the distance to the head 24 from the charges in the hard magnetic layer 12. These distances are illustrated by the dashed lines 28 and 30, respectively. Thus, the signal from the soft magnetic layer 16 image is almost as strong as that from the hard layer 12 but opposite in sign. The two signals nearly cancel any effect on the adjacent track 22 which is being read by the head 24.

When the head 24 is directly above the track 22 of interest, the situation becomes very complex. This is the case because the head is also made from a soft magnetic material and will have image charges induced in it. These induced virtual charges in the head in turn induce virtual charges in the soft magnetic layer 16 and so on. The head thus sees an infinite series of repeating image charges similar in effect to the infinite series of images seen when one looks at the reflection of a mirror in another mirror. Although one would expect such an effect to result in cancellation of the signal from the track of interest, the applicant herein has determined this not to be the case. An exact analysis indicates only a weak suppression of the high frequency on-track signal (e.g., at 30 kfri, with an effective fly height of 10 microinches and a nonmagnetic buffer layer 14 thickness of 10 microinches, the loss of high frequency amplitude to the buffer layer is 11.6%).

The net effect of the magnetic medium 10 is that off-track interference is reduced while the signal from the track of interest is only slightly affected. The suppression of low frequency signals is much greater than that of high frequency signals so the resolution (high frequency amplitude divided by low frequency amplitude) is also improved without resorting to electronic equalization which usually amplifies the noise as well.

The thickness of the nonmagnetic buffer layer 14 may range from zero to roughly the distance of closest approach of the head to an adjacent track. Optimum performance under ordinary conditions will be obtained in the thickness range from 0.5 to two times the effective fly height. The effective fly height is equal to the sum of the actual fly height of the head, F, the pole tip recession, the thickness of any overcoat layer over the hard magnetic layer 12, and one-half the thickness of the hard magnetic layer 12. As the nonmagnetic layer is made thinner, off-track signal suppression increases but on-track high frequency amplitude decreases. An engineering tradeoff must be made between these two effects. The soft magnetic layer 16 should be slightly greater in magnetic thickness than that of the hard layer (e.g., 30% greater) so that it can absorb all of the flux from the off-track signal without saturating. If it is made too thick, however, this layer suppresses the write process in proportion to its thickness.

When a two-pole head is used to read (a three-pole head is preferred), two potential problems may arise. A first problem is that the pole corners will generate strong negative dips (e.g., 25% of the isolated signal for buffer thickness equal to effective

fly height). This situation can be remedied either by electronic equalization or by beveling the pole corners so that the dips are softened. A second problem is that the soft layer 16 will tend to short out the poles and reduce the head efficiency. To overcome this problem and reduce the negative dip problem, the permeability of the soft magnetic layer 16 can be deliberately reduced resulting in a semisoft layer. This will decrease the strength of the high order images but will also reduce the pole shorting effect. Finally, as another alternative, a weak magnetic field may be applied to the medium during a read, at a strength large enough to saturate the soft layer and so to cancel the effect of the image charges below the head, but not strong enough to affect the hard magnetic recording layer. This technique would allow the use of very thin buffer layers and would also help with the problems associated with using a two-pole head to read.

The magnetic medium according to the invention is made by beginning with a polished Ni-P on aluminum standard substrate. A soft magnetic layer such as NiFe is deposited on the substrate. As stated above, the thickness of the soft magnetic layer should be approximately 30% greater than the hard magnetic layer to be deposited later. A uniaxial anisotropy is induced in a radial direction (the medium will normally be disc-shaped) in the soft magnetic layer by applying a field during deposit, by performing an anneal in a magnetic field later, by controlling the angle of incidence in the case of vacuum deposition, or by pretexturing the substrate. If a semisoft layer is desired (for two-pole head operation), then a high Hk alloy such as NiFeCo, NiCo, or CoZr is used. A nonmagnetic buffer layer (e.g., Ni-P for plating or Cr

for sputtering) is next deposited. The thickness of this layer is in the range of 0.5 to two times the effective fly height. A hard longitudinal magnetic layer is then deposited by conventional means and finally an overcoat is deposited.

The magnetic medium of the present invention reduces fringing at high track density and improves resolution. When a three-pole head is used, the fringing is so strongly suppressed that the bottom pole can be made significantly oversized. In this way the need for on-wafer track trimming of the whole head is eliminated.

It is recognized that modifications and variations of the present invention will occur to those skilled in the art and it is intended that all such modifications and variations be included within the scope of the appended claims.

CLAIMS

1. Magnetic medium for longitudinal recording comprising a soft magnetic layer disposed beneath a hard magnetic recording layer.

2. The medium of claim 1 further including a nonmagnetic layer between the soft magnetic layer and the hard magnetic layer.

3. The medium of claim 1 wherein the thickness of the soft magnetic layer is greater than the thickness of the hard magnetic layer.

4. The medium of claim 3 wherein the magnetic thickness of the soft magnetic layer is approximately 30% greater than the hard magnetic layer.

5. The medium of claim 2 wherein the magnetic layer thickness is in the range of 0.5 to two times the effective fly height of a magnetic head.

6. The medium of claim 2 wherein the thickness of the soft magnetic layer is greater than the thickness of the hard magnetic layer.

7. The medium of claim 2 wherein the magnetic thickness of the soft magnetic layer is approximately 30% greater than the hard magnetic layer.

8. Magnetic medium for longitudinal recording in a system in which a head passes over the medium at an effective fly height comprising:

a hard magnetic layer adjacent to the head;

a nonmagnetic layer beneath the hard magnetic layer; and

a soft magnetic layer beneath the nonmagnetic layer.

9. The medium of claim 8 wherein the soft magnetic layer thickness is greater than the hard magnetic layer thickness.

10. The medium of claim 8 wherein the nonmagnetic layer thickness is in the range of 0.5-2 times the effective fly height.

11. The medium of claim 1 or claim 2 wherein the soft magnetic layer has low permeability.

12. Recording system comprising:

a head; and

a recording medium comprising a nonmagnetic layer disposed between hard and soft magnetic layers; the head adapted to generate magnetic fields during read to saturate the soft magnetic layer.

13. Method for making a longitudinal recording medium comprising:

depositing a soft magnetic layer on a substrate;

inducing a uniaxial anisotropy in a radial direction in the soft magnetic layer;

depositing a nonmagnetic layer on the soft magnetic layer; and

depositing a hard magnetic layer on the nonmagnetic layer.

14. The method of claim 13 wherein the uniaxial anisotropy is induced by an applied magnetic field during deposition.

15. The method of claim 13 wherein the uniaxial anisotropy is induced by annealing the medium in a magnetic field.

16. The method of claim 13 wherein the uniaxial anisotropy is induced by controlling the angle of incidence during vacuum deposition.

17. The method of claim 13 wherein the uniaxial anisotropy is induced by pretexturing the substrate.

18. The medium of claim 2 wherein the nonmagnetic layer is NiP.

19. The medium of claim 1 or claim 2 wherein the soft magnetic layer is NiFe.

20. The medium of claim 1 or claim 2 wherein the soft magnetic layer is NiFeCo.

21. The medium of claim 1 or claim 2 wherein the soft magnetic layer is NiCo.

22. The medium of claim 1 or claim 2 wherein the soft magnetic layer is CoZr.

23. The medium of claim 2 wherein the nonmagnetic layer is Cr.

24. The medium of claim 1 or claim 2 wherein the soft magnetic layer has a uniaxial anisotropy.

25. The medium of claim 24 wherein the uniaxial anisotropy is in a radial direction.

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 88/03453

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^4: G 11 B 5/66

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^4	G 11 B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	WO, A, 87/03728 (AMPEX CORP.) 18 June 1987 see claims 1,2,4; page 10, lines 22-37; page 12, lines 7-17; page 15, lines 15-25	1,3,19
Y		2,6,8,9, 12
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Y	EP, A, 0178685 (SONY CORP.) 23 April 1986 see claims 1-3; example 1	2,6,8,9, 12
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A	DE, B, 1153069 (MAX GRUNDIG) 22 August 1963 see claims 1,4; column 1, lines 32-49	1
	--	
A	IBM Technical Disclosure Bulletin, volume 23, no. 7A, December 1980, (New York, US), T.N. Kennedy: "Magnetic recording disk with buried servo layer", pages 2949-2950 see figure 2; page 2949, line 13 - ./.	1

* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
2nd January 1989	17. 01. 89
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	P.C.G. VAN DER PUTTEN

International Application No. PCT/US 88/03453

III. D CUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FR M THE SEC ND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
	page 2950, line 4 --	
A	Patent Abstracts of Japan, volume 8, no. 183 (P-296)(1620), 23 August 1984, & JP, A, 5972644 (NIPPON DENKI K.K.) 24 April 1984 --------	1

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. US 8803453 SA 24763

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 11/01/89
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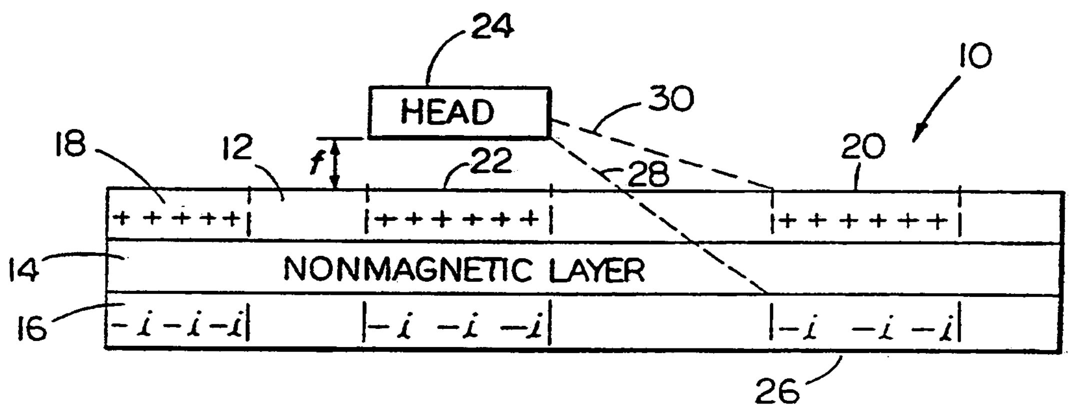
WO-A- 8703728	18-06-87	AU-A- 6847487	30-06-87
		EP-A- 0250560	07-01-88
		JP-T- 63501753	14-07-88
EP-A- 0178685	23-04-86	JP-A- 61099932	19-05-86
DE-B- 1153069		None	

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82


24
10
HEAD
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12
f
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14
NONMAGNETIC LAYER
16
-i -i -i
-i -i -i
-i -i -i
26

FIG.1